Ammonia and Other Nitrogen Compound Emission Fluxes From Non-Enteric Sources at Six California Dairies

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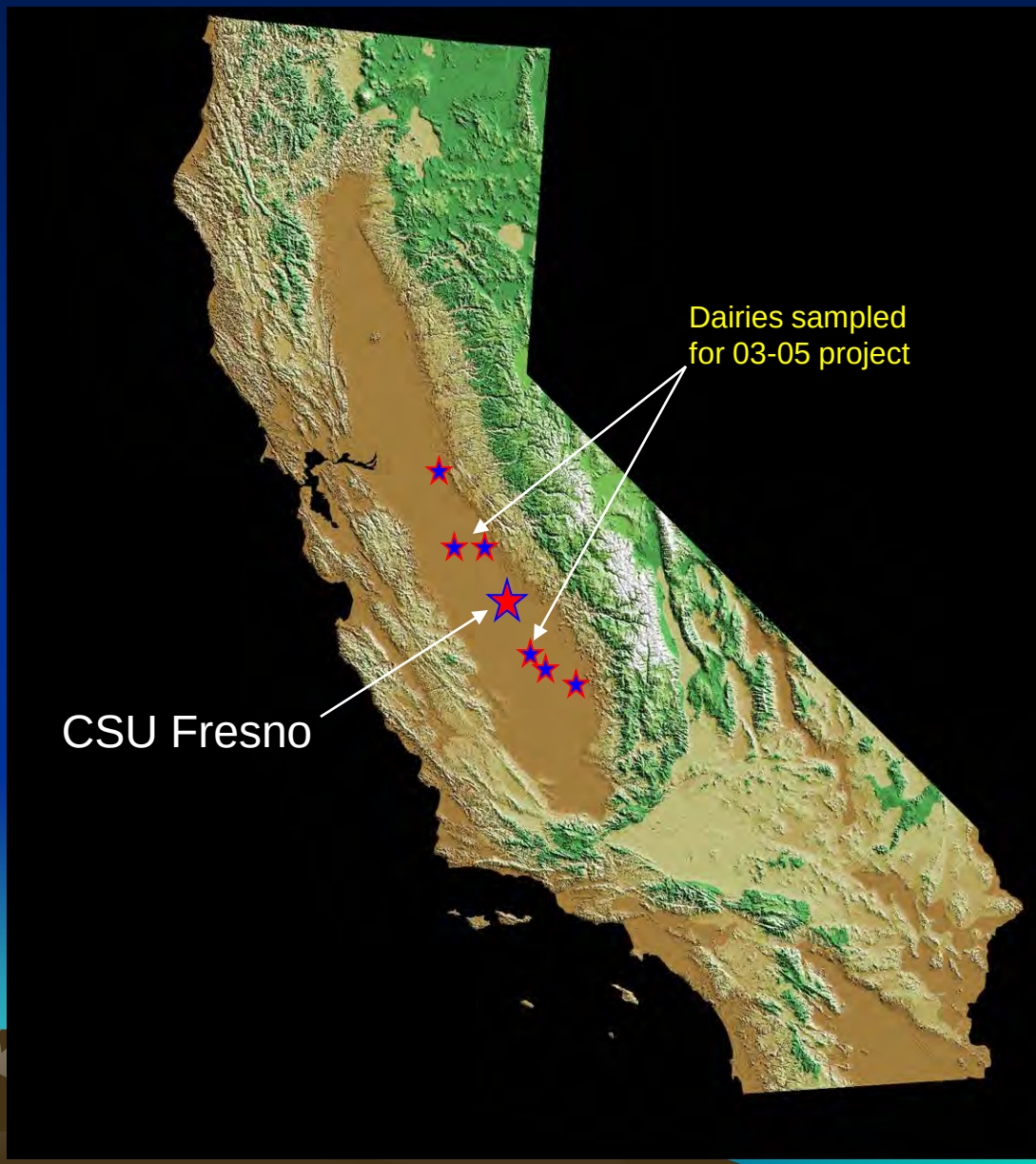
Secondary Funding for the Ammonia study: USDA CSREES

CSU-Fresno Dairy Air Quality Projects in the Central Valley of California

- An initial study was done at two dairies from 2003-05. Upwind and downwind samples were collected and emission rates were estimated using dispersion modeling.
- That preliminary study was augmented in 2005 by ARB to include cooperation with UC Irvine for speciation of VOC's and to identify the dominant ROG's from specific operations.
- That cooperative study focused on the relative ROG fluxes from various operations at six dairies with collection of ammonia and other N compound data added as secondary projects supported by additional funding sources.

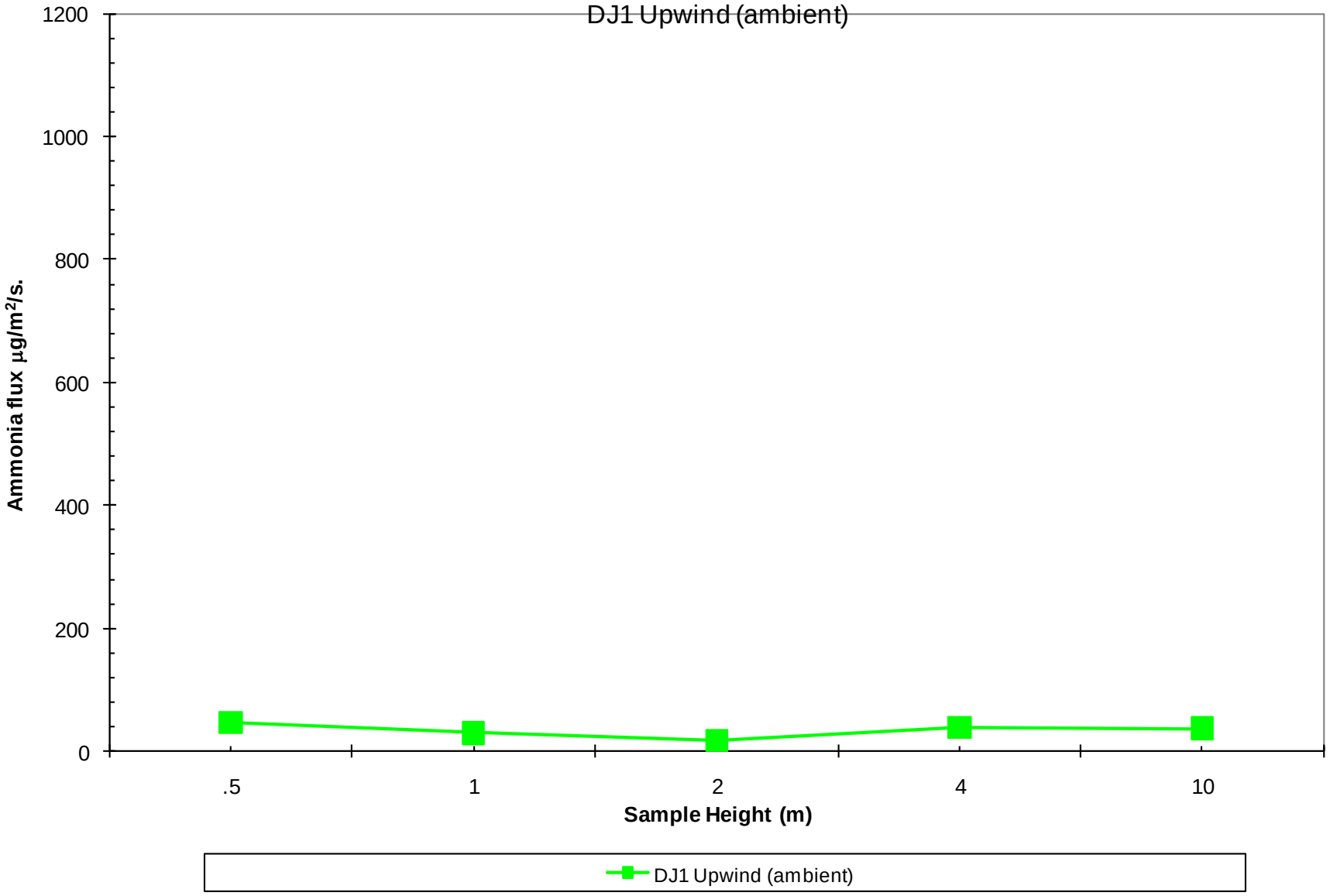


Kings County Dairy. A 2000 cow dairy located 10km east of Hanford. The dairy utilizes "free stall" management where the cows are fed on gently sloping concrete that is flushed with a large flow of water several times a day to remove the waste. Solids in the flush water are separated from the liquid which is stored in a series of lagoons for subsequent flushing of the free stalls and eventually is part of the irrigation water for the surrounding cropland.

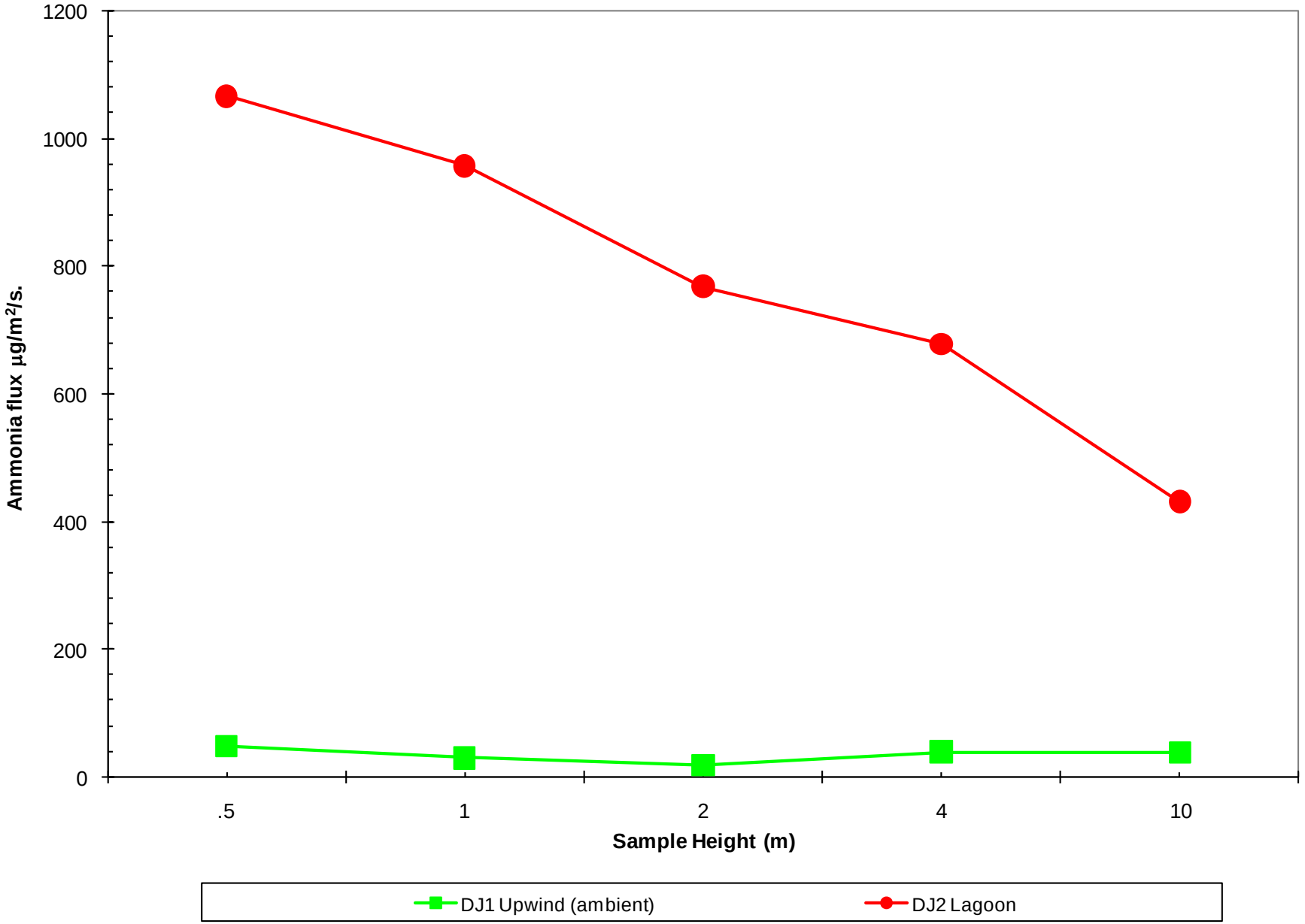
The dairy is surrounded by sorghum and alfalfa fields that are used to recycle nutrients from the dairy waste and to produce forage for the dairy herd.

Three sampling sites were located at the dairy: an Up-Wind Fenceline site, a Down-Wind Fenceline site and a Down-Wind Field site.

Up Wind Fenceline site (DW1). Looking SE, downwind.


DJ1 Upwind (ambient)
1200
1000
800
600
400
200
0
Ammonia flux µg/m²/s.
.5
1
2
4
10
Sample Height (m)
DJ1 Upwind (ambient)

Ammonia sampling site, Kings Co. dairy, Down-Wind of the Lagoon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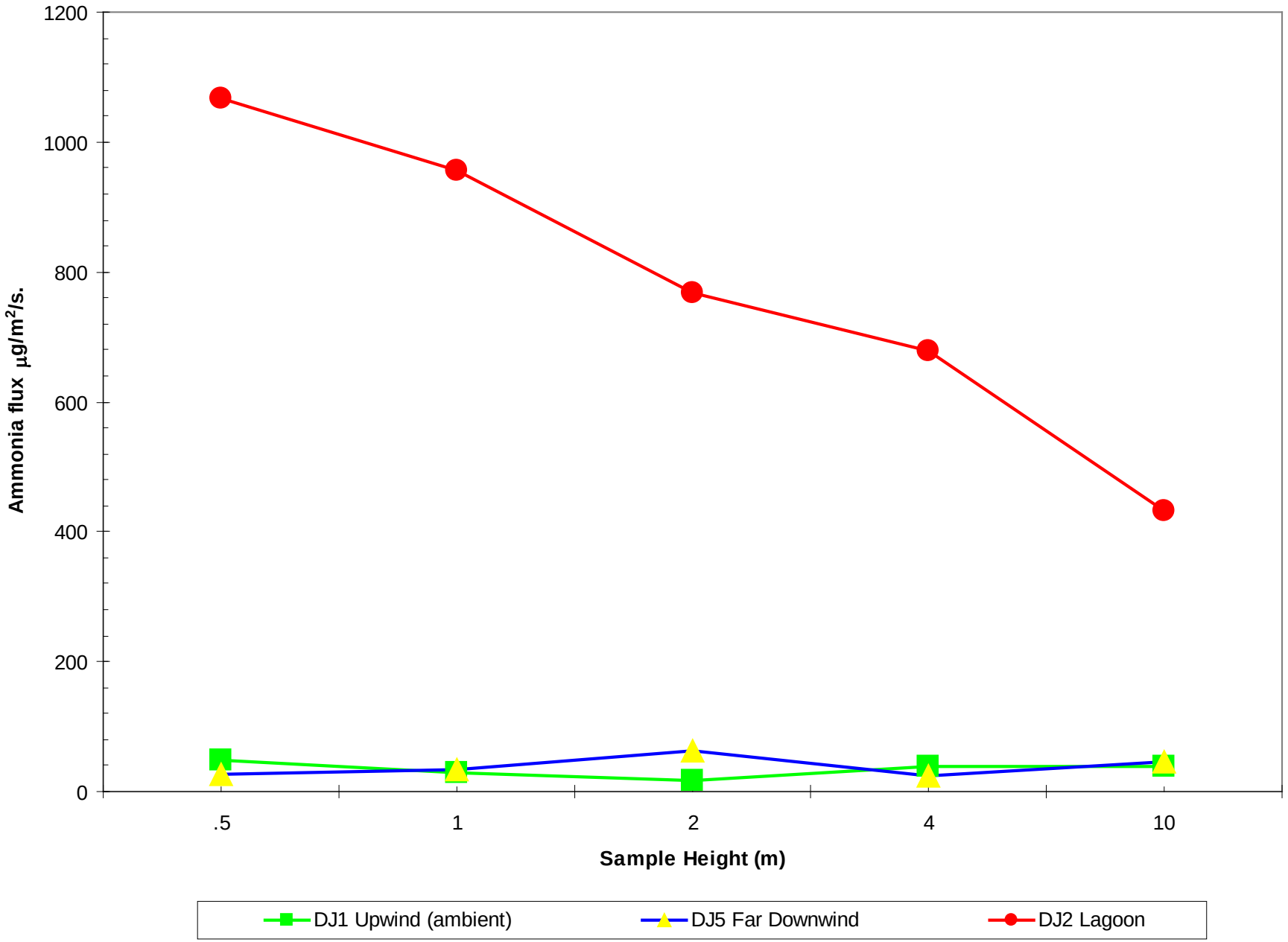
0
Ammonia flux µg/m²/s.
.5
1
2
4
10
Sample Height (m)
DJ1 Upwind (ambient)
DJ2 Lagoon

Downwind Field site (DW3) looking NW to the Down Wind Fenceline site, 300m across the field at the “O”


1200
1000
800
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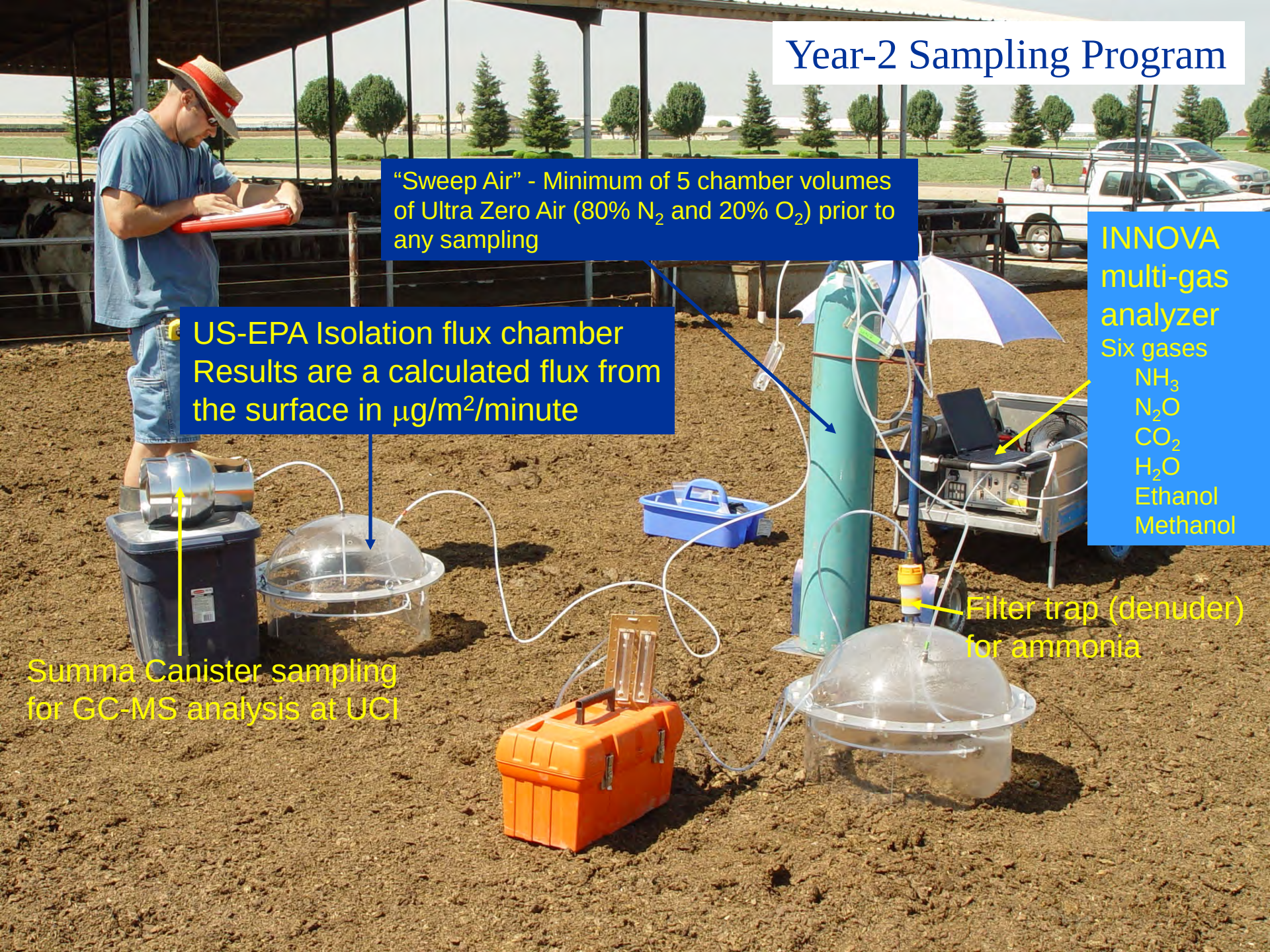
0
Ammonia flux µg/m²/s.
.5
1
2
4
10
Sample Height (m)
DJ1 Upwind (ambient)
DJ5 Far Downwind
DJ2 Lagoon

Year-2 Sampling Program



Fluxes from the silage pile face compared to disturbed silage at Dairy A

Flux Chamber monitoring of flush lane at Dairy B

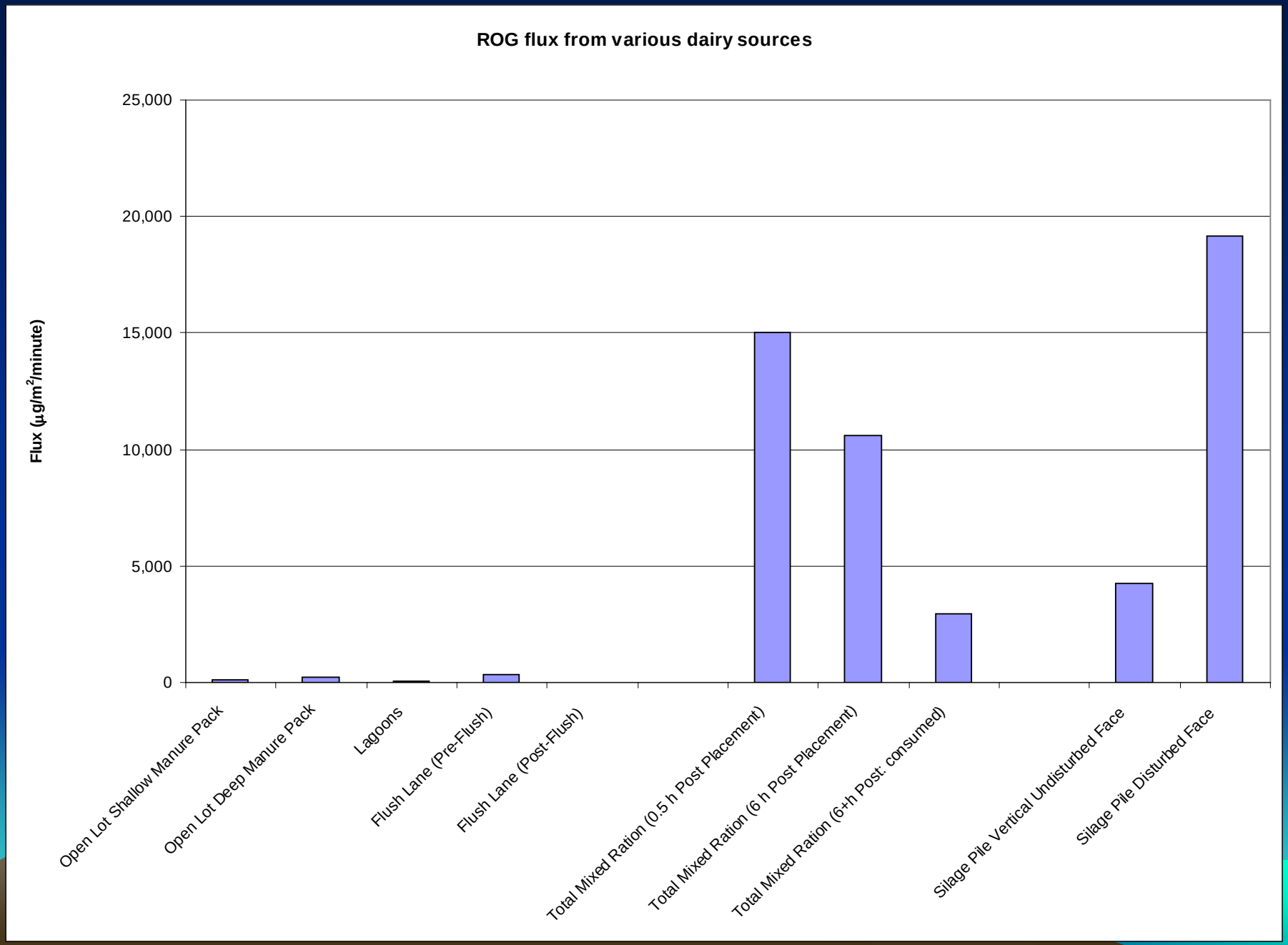
Sampling ethanol, methanol, ammonia, N_2O and ROG's from Total Mixed Ration (TMR) using flux chambers at Dairy A.

Table 10. Average flux rates for all dairies, all dates and each dairy operation included in the regular sampling program for Year-2. The 6 major components of ROG are reported here. The UC Irvine analysis included ROG components from a list of 64 gasses identified in the analytical procedure. Values are in μg/m^2/minute and are corrected by the subtraction of Field Blank values.

Flux Rate in μg/m^2/minute

	Total ROG	Ethanol	Ethanol	Metanol	Metanol	**Total Alcohols**	**Total Alcohols**	Acetaldehyde	Acetaldehyde	d-Limonene	d-Limonene	DMDS	DMDS	DMS	DMS
Open Lot Shallow Manure Pack	102	15	22%	17	24%	45	56%	35	19%	1	1%	0	0%	12	10%
Open Lot Deep Manure Pack	243	20	22%	28	25%	60	57%	69	14%	1	1%	0	0%	74	14%
Flush Lane (Pre-Flush)	353	22	9%	9	8%	108	47%	20	11%	7	6%	0	0%	12	2%
Flush Lane (Post-Flush)	21	3	34%	1	13%	6	53%	0	2%	0	3%	0	0%	0	1%
Total Mixed Ration (0.5 h Post Placement)	15,022	11,668	75%	1,460	11%	13,141	86%	336	3%	584	4%	26	0%	831	5%
Total Mixed Ration (1.5 h Post Placement)	4,507	3,394	78%	547	12%	3,941	90%	15	0%	459	7%	34	2%	12	0%
Total Mixed Ration (6 h Post Placement)	10,582	7,747	69%	1,591	18%	9,350	87%	469	5%	557	5%	9	0%	152	1%
Total Mixed Ration (6+h Post: consumed)	2,929	2,289	69%	389	19%	2,683	89%	106	5%	102	4%	3	0%	32	2%
Silage Pile Vertical Undisturbed Face	4,229	3,095	76%	416	10%	3,524	86%	164	4%	6	0%	1	0%	532	11%
Silage Pile Disturbed Face	19,170	12,814	75%	632	8%	13,461	84%	214	3%	49	0%	1	0%	5,413	13%

ROG fluxes (μg/m²/minute) from various sources at six valley dairies in 2007-08



Flux values for various sources multiplied by the area represented by those sources at a "composite diary" averaged from the six sites sampled in the study.

Disturbed Silage
Average flux (Table 10) = 19,170 μg/m^2/minute
Estimated area at the fictitious dairy = 25 m^2
Estimated emission = 19,170 μg/m^2/minute X 25 m^2 X 1440 min/day = 0.7 kg/day

Undisturbed Silage
Average flux (Table 10) = 4,229 μg/m^2/minute
Estimated area at the fictitious dairy = 250 m^2
Estimated emission = 4,229 μg/m^2/minute X 250 m^2 X 1440 min/day = 1.5 kg/day

TMR (average of all sample periods)
Average flux (Table 10) = 8,260 μg/m^2/minute
Estimated area at the fictitious dairy = 1600 m^2 (1m wide x 400m long x 4 bunkers)
Estimated emission = 8,260 μg/m^2/minute X 1600 m^2 X 1440 min/day = 19.0 kg/day

Flush lanes (average of pre-flush and post-flush)
Average flux (Table 10) = 187 μg/m^2/minute
Estimated area at the fictitious dairy = 9600 m^2 (3m wide x 400m long x 8 lanes)
Estimated emission = 187 μg/m^2/minute X 9600 m^2 X 1440 min/day = 2.6 kg/day

Open Lots (average of deep and shallow manure pack)
Average flux (Table 10) = 172 μg/m^2/minute
Estimated area at the fictitious dairy = 32,000 m^2 (20m wide x 400m long x 4 lots)
Estimated emission = 172 μg/m^2/minute X 32,000 m^2 X 1440 min/day = 7.9 kg/day

Emission rates estimated from the fluxes monitored in the study and applied to estimated source sizes at a “composite dairy” averaged from the six sites monitored in 2005-08.

ROG emissions from the fictitious dairy and their relative percentages of the total:

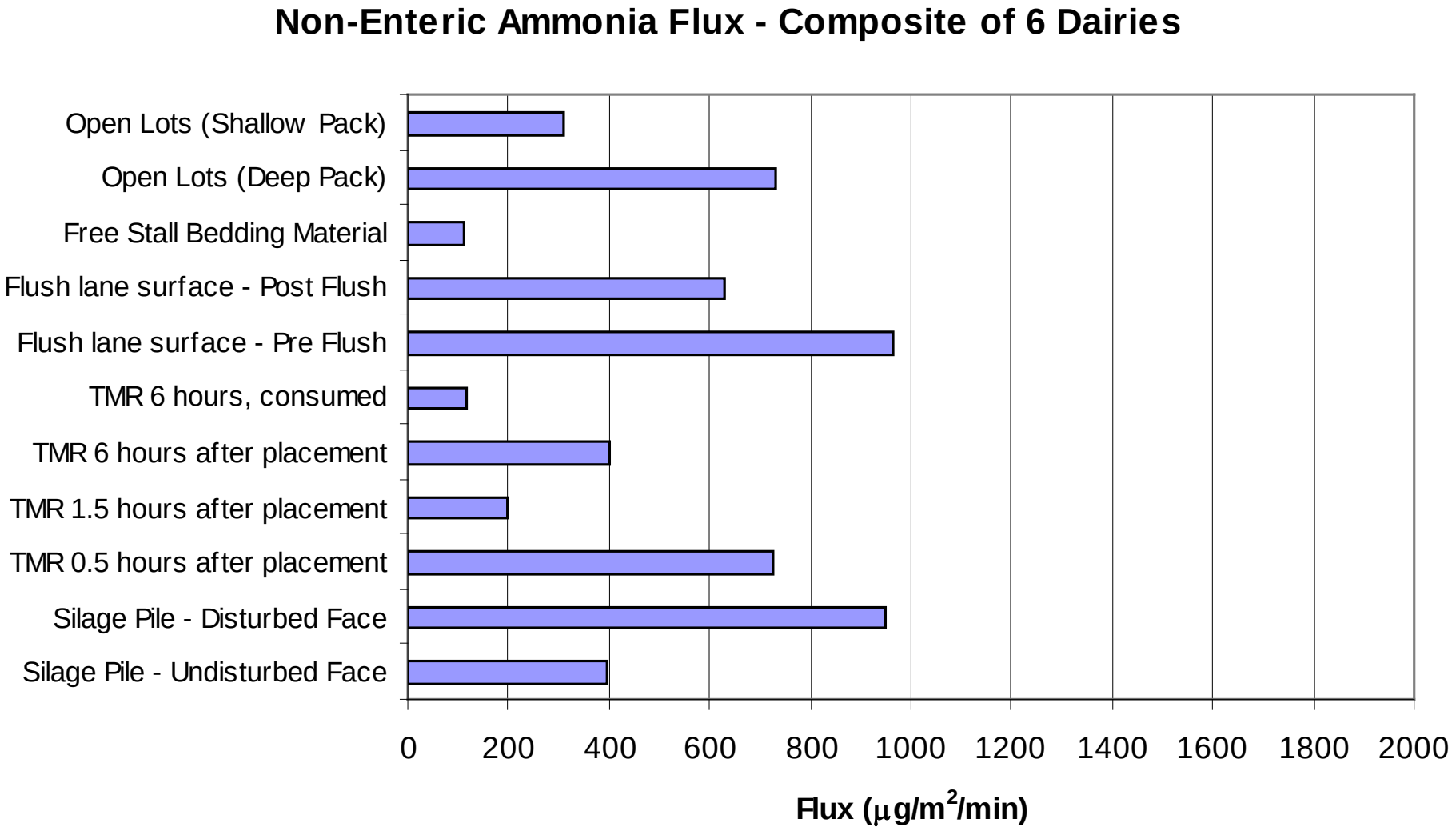
Disturbed Silage…... 0.7 kg/day (2%)
Undisturbed Silage... 1.5 kg/day (5%)
TMR…….. 19.0 kg/day (60%)
Flush lanes…….. 2.6 kg/day (8%)
Open Lots…….. 7.9 kg/day (25%)
Total ……..31.8 kg/day (100%)

The composite dairy milked 2000 cows so conversion of the 31.8 kg/day to the units used for regulation by the local air district gave a value of 12.8 lb./head/yr. Additional monitoring and further data analysis will provide a more accurate range of emission rates for these sources.

Collaborative Projects funded by Additional Support

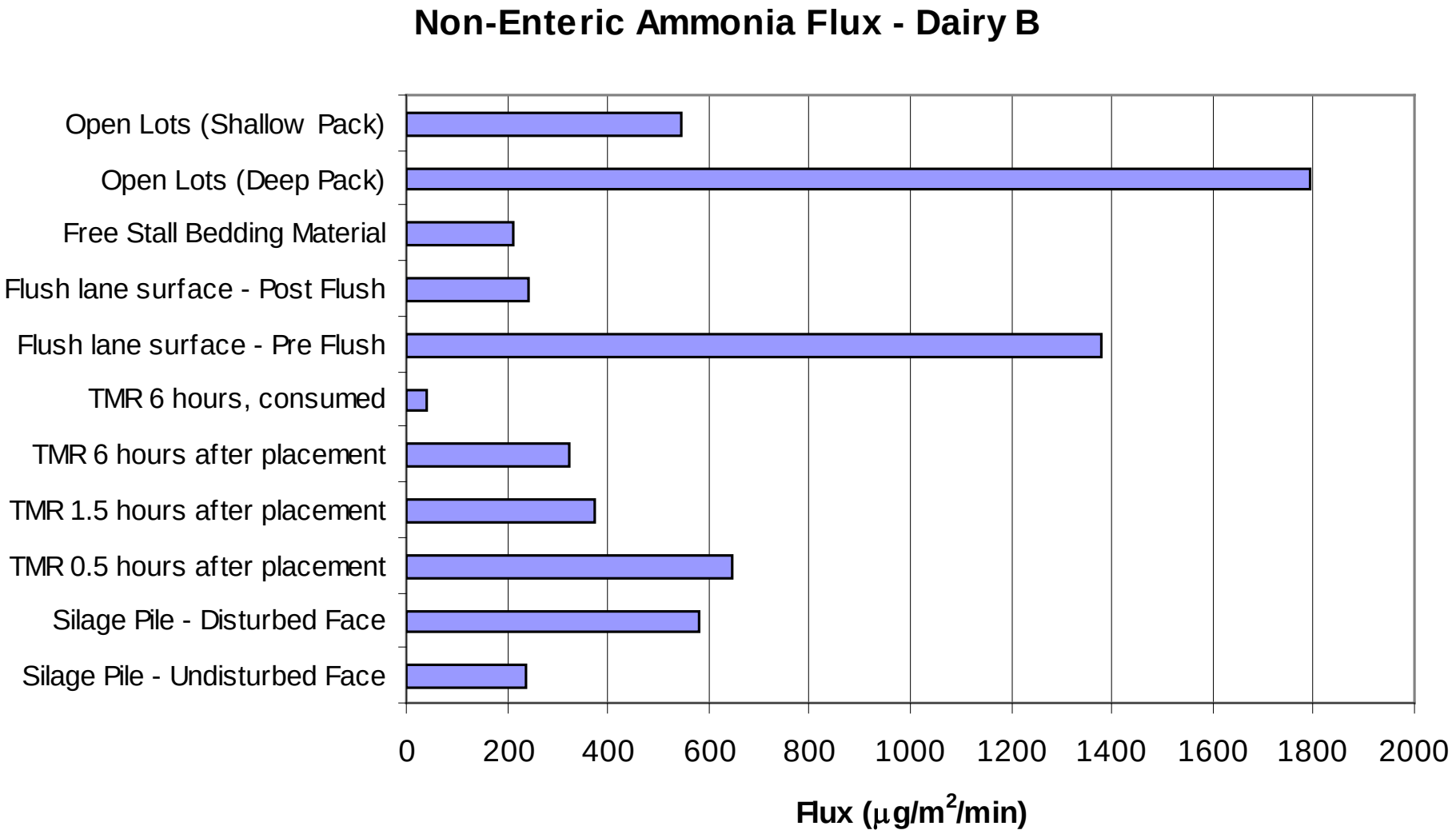
- USDA-CSREES funding added Ammonia and other N compound monitoring for UNH (Salas and Li) as well as further study of alcohols with UCD (Mitloehner et al).
- Land Application fluxes were monitored for Sustainable Conservation Inc.
- Photosynthetic lagoon fluxes were compared to traditional lagoon systems for the CA Dairy Campaign.
- CSU Agricultural Research Initiative funding matched many of these externally funded projects to extend their terms and expand their scope.

Ammonia and other N fluxes for DNDC model validation
USDA-CSREES subcontract for U New Hampshire (Salas and Li)



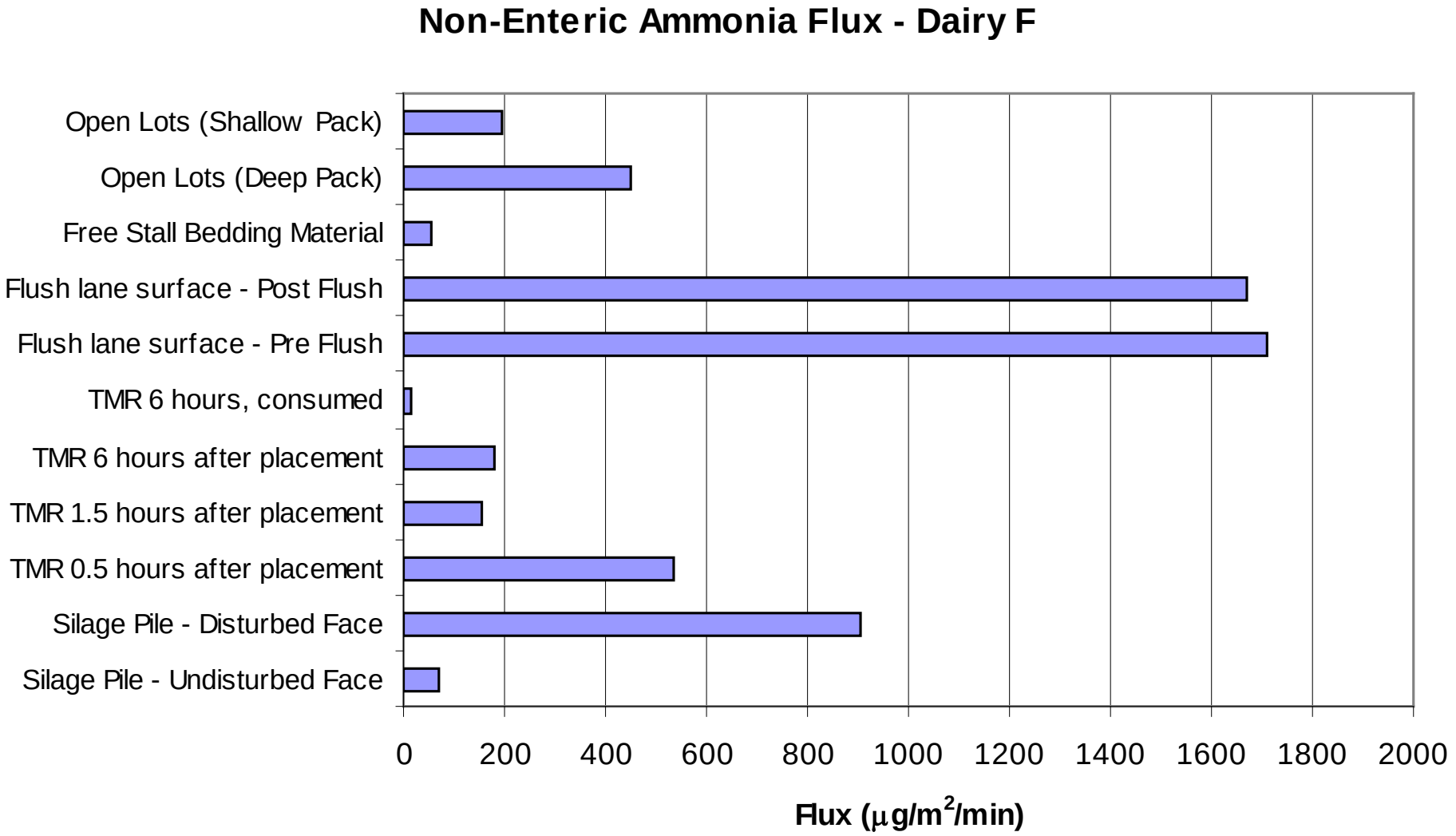
Ammonia and other N fluxes for DNDC model validation
USDA-CSREES subcontract for U New Hampshire (Salas and Li)

Dairy B has a single lagoon and manages the manure pack in the corrals infrequently



Ammonia and other N fluxes for DNDC model validation
USDA-CSREES subcontract for U New Hampshire (Salas and Li)

Dairy F scrapes the manure slurry rather than flushing it and intensively manages the small corrals



Ammonia and other N fluxes for DNDC model validation
USDA-CSREES subcontract for U New Hampshire (Salas and Li)

Estimated Ammonia Flux for the Composite of 6 Dairies

SOURCE	Estimated Unit Area (m^2)	Number of Units	Ammonia Flux $\mu g/m^2/min$	Time Fraction per Day	Estimated Emission (kg/day)	Fraction of the total		
Silage Pile - Undisturbed Face	250	1	395	100%	0.14	0.5%		
Silage Pile - Disturbed Face	25	1	948	100%	0.03	0.1%	0.6%	Total Silage
TMR 0.5 hours after placement	800	2	725	13%	0.21	0.7%		
TMR 1.5 hours after placement	800	2	197	38%	0.17	0.6%		
TMR 6 hours after placement	800	2	400	25%	0.23	0.8%		
TMR 6 hours, consumed	800	2	117	25%	0.07	0.2%	2.3%	Total TMR
Flush lane surface - Pre Flush	4800	2	966	50%	6.67	22.7%		
Flush lane surface - Post Flush	4800	2	631	50%	4.36	14.9%	37.6%	Total Lanes
Free Stall Bedding Material	3600	2	114	100%	1.18	4.0%		
Open Lots (Deep Pack)	800	4	733	100%	3.38	11.5%		
Open Lots (Shallow Pack)	7200	4	312	100%	12.92	44.0%	55.5%	Total Lots
				Sum =	**29.4**			
				Dairy A	10.9			
				Dairy B	98.9			
				Dairy C	3.1			
				Dairy D	69.3			
				Dairy E	32.5			
				Dairy F	59.9			

Fluxes from lightly loaded, photosynthetic lagoons for the CDC

Summary of Lagoon Emissions

	Ammonia NH3-N	Nitrous Oxide (NO2-N)	Carbon Dioxide	Methane	Acetic Acid	Ethanol	Methanol	Tri-methylamine	2-Propanol
Magnussen (6)	258	55	9,269	84	1,120	U	58	298	315
Hilltop Holsteins (6)	315	1	61,286	18,879	1	16	246	992	1,066
Verburg (8)	183	7	20,489	10,806	3	7	186	686	1,159
Dairy A (8)	209	3	88,531	45,668	31	U	366	1,518	890
Dairy B (4)	219	2	65,538	30,994	U	U	330	1,241	1,563
Dairy D (8)	475	5	46,162	15,914	12	U	418	1,212	3,856
Photosynthetic Lagoons	252	21	30,348	9,923	375	12	163	659	847
Conventional Lagoons	317	3	66,985	30,831	19	U	379	1,340	2,211

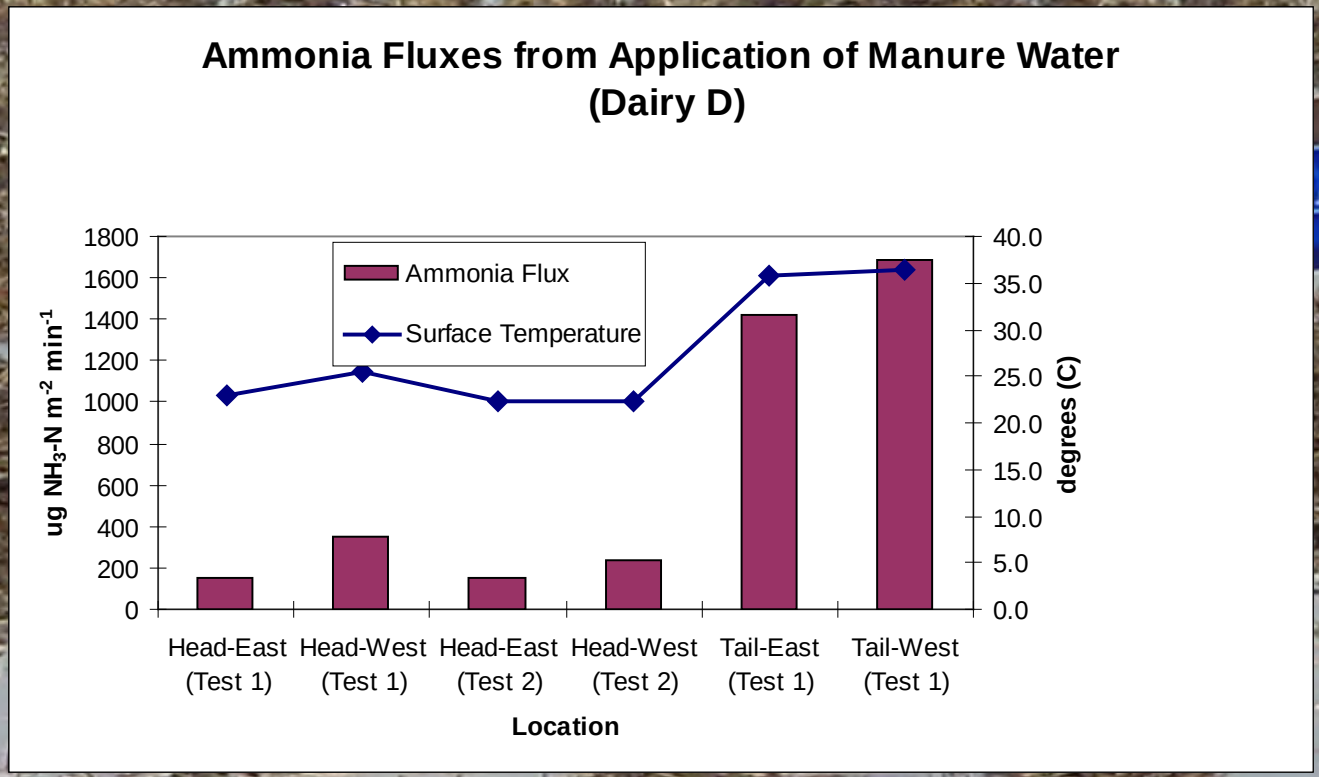
Values in the table are “flux rates” in $\mu g/M^2$/minute.

“U” indicates a value below the detection limit of the INNOVA analyzer.

The values are corrected by subtracting the field blank from the measured value.

The number of samples averaged for each dairy is shown in parenthesis.

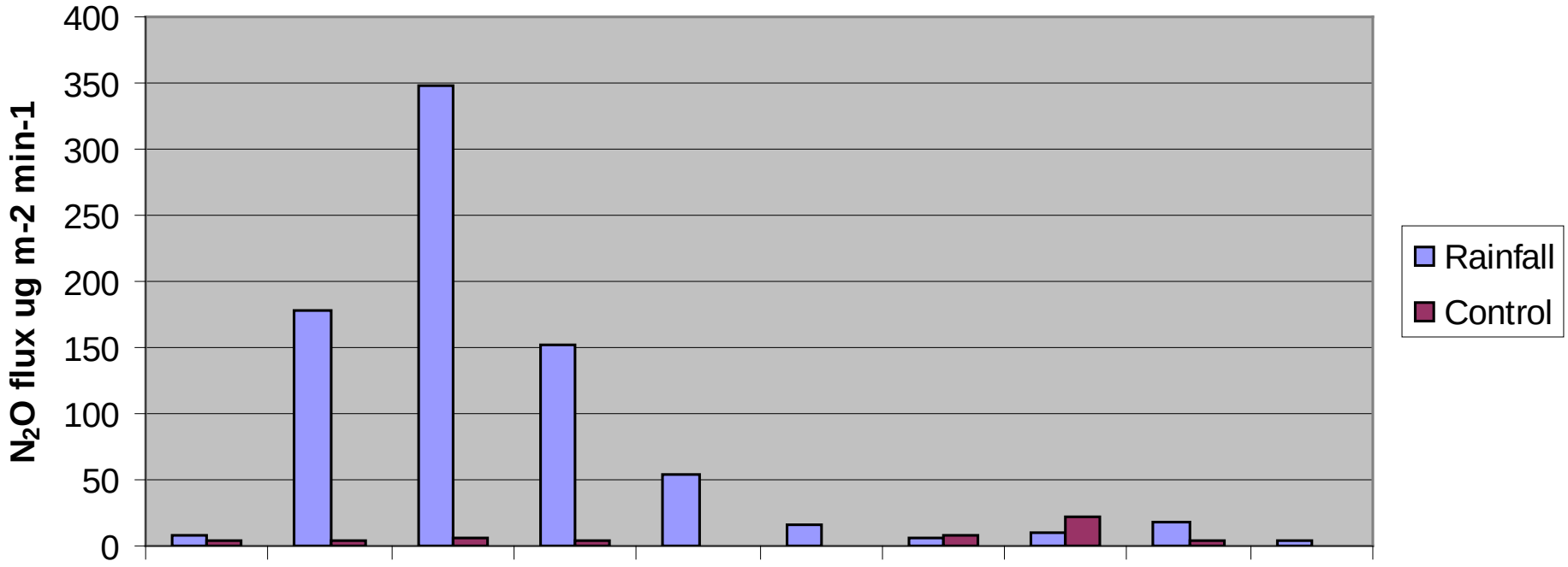
Land Application of Lagoon Effluent at Dairy D (June, 2006)



A rain event was simulated at the CSU Fresno Dairy to test the hypothesis that temporary anaerobic conditions in the manure pack would elevate N_2O emissions in the highly organic matrix.

- A sprinkler was set up to apply 20mm of water in 4 hours to simulate the initial Central Valley winter storm on an exercise corral at the CSUF dairy.
- An area was covered by a tarp to maintain a control area.
- Flux chambers were set up to measure the emission flux from the manure surface before and after the simulated rain.
- A spike of N_2O occurred for about 8 hours following the end of the “rain event”.

N_2O-N Emissions - Simulated Rainfall Test
CSUF Dairy



- A real rain event a month later did not show elevated N_2O flux. That may have been due to the fact that the temperatures were much colder by the time of the real rain in December.

Cautionary Disclaimer

- The EPA Isolation Flux Chamber samples the emissions from the surface it covers by excluding ambient air. Fluxes calculated from this sampling method may be higher than actual surface fluxes of some or all gases sampled because:
  - Equilibrium exchange processes between the surface and the atmosphere are affected by the replacement of the ambient air by sweep air in the chamber.
  - Exchange processes and adsorption by other surfaces at the dairy are not sampled by the flux chamber and so the actual facility emission is likely to be lower than these estimates.

  Consequently, data from this study should be used for comparing relative emissions from different practices and conditions at the dairies rather than determining facility emission rates or factors.


QUESTIONS?